CHAR PRODUCTION THROUGH THE CO-PYROLYSIS OF COAL AND BIOMASS IN A FIXED FED REACTOR

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Abstract

Coal contributes to 40% of the world's energy production and the process of energy production from coal contributes to 40% of the world's carbon dioxide emissions which have led to global warming and climate change. Thermochemical processes like pyrolysis, gasification and carbonification are used to utilize coal and this coal can be mixed with other sources of energy such as biomass for environmental protection, a higher energy densification and char yield. In this study Morupule coal was co-pyrolyzed with cow dung in a fixed bed reactor with the aim of producing char whilst reducing the net carbon dioxide emissions. Co-pyrolysis of coal with biomass yields char, gas and liquid fuel. Char is used in various sectors such as agriculture to improve soil quality hence increasing crop yields and as an adsorbent for wastewater treatment. The co-pyrolysis process was performed at 500^{o}C and atmospheric pressure under an inert atmosphere which contained argon. Pyrolysis using a fixed bed reactor was performed on coal and cow dung at blend ratios of coal to cow dung of 0:100, 50:50, 60:40, 70:30, 80:20, 90:10, and 100:0. Proximate analysis results indicated that char had a higher fixed carbon compared to those from the individual substrates. Calorific value (CV) tests of the chars indicated that reducing to 90:10 ratio the cow dung concentration resulted in CV increases. This study shows that there is a synergic effect between the sub-bituminous Morupule coal and cow dung.

Keywords: Cow dung, Char, Coal, Fixed bed reactor, Co-pyrolysis

1 INTRODUCTION

Global warming is one of today's challenges threatening human life and the environment and it results from the release of gases such as carbon dioxide, sulphur dioxide and nitrogen dioxide into the atmosphere from combustion of fossil fuels. Ash disposal problems are also associated with the combustion of fossil fuels. This has motivated research that is focused on reducing global warming threats such as underground gasification and surface energy systems aimed at eliminating ash disposal problems and providing economic coal exploitation and utilization [1]. Thermochemical means such as gasification, liquefaction and pyrolysis can be used in coal utilization. Co-utilization of coal with biomass is employed as a means of utilizing coal [2]. Wei et al. [3] reported on the effects of feedstock on co-pyrolysis of biomass and coal in a free-fall reactor and the results indicated that there is a synergic effect between coal and biomass. Bituminous coal with Dayan brown, agricultural residues legume straw and woody residues pine sawdust were utilized, and it was observed that the liquid yield from bituminous coal was much higher than that of the Dayan brown coal.

In an effort to reduce the production of greenhouse gases, pyrolysis and gasification of low rank coals (coals with a low carbon content) which include lignite and sub-bituminous coal, and biomass feeds have been a subject of a study by Soncini et al.[4]. In the study, a semi-batch reactor was used to pyrolyze sub-bituminous or lignite coal with south yellow pine at various temperatures. The results showed that synergies of co-pyrolysis become more significant as the rank of coal goes down. Lignite and sub-bituminous coals contain larger pores and smaller clusters of aromatic structures which are more rapidly retained as tar in rapid co-pyrolysis [4].

Biomass is a clean energy source with less environmental threats compared to fossil fuels as it is renewable that is, the carbon emitted is then used to create more biomass through photosynthesis. Li et al. [5] investigated the co-pyrolysis characteristic of biomass and bituminous and lignite coal in a thermogravimetric analyser (TGA) of WRT-3P. The biomass studied were rice straw, saw dust, microcrystalline cellulose and lignin with biomass to coal ratios varied from 0% to 100% coal were pyrolyzed. Synergy between lignite coal and biomass were observed at higher biomass composition and the influence of the biomass type, blend composition, and process temperature of hybrid coal pyrolysis were investigated by Sasongko et al. [6]. Experiments were performed at 200, 300 and 400ºC while biomass waste blend with hybrid was at 15%, 22.5% and 30%. Results showed that co-pyrolysis of biomass and lignite coal increases the char calorific value for which the char can be used in combustion plants with less environmental hazards. The influence of temperature and pressure as well as blending ratio on the coal pyrolysis of bituminous coal and biomass in a pressurised fluidised bed reactor was reported with improved tar quality [7] and the results indicated that a synergic effect exists between biomass and bituminous coal

In this paper, the authors report on the co-pyrolysis of coal and cow-dung. Botswana is a cattle rich country, and its beef industry value chain produces a lot of waste in particular cow dung. Cow dung is a nuisance to the environment as it can lead to rivers and underground water contamination and methane emission into the atmosphere if left scattered, uncollected and unutilized. Botswana has about 2.2 million cattle where each cow produces approximately 3kg dung/ day. It is a valuable energy source, and it is available in large quantities. Although, there are attempts at a smaller scale to utilize manure for biogas production there are no reported attempts to produce char and other forms of fuel through thermochemical processes from manure in Botswana. Botswana also has an abundance of coal which is estimated to be 212 billion tonnes which is the second largest in Africa, after South Africa. Botswana coal is sub-bituminous mainly utilized for electrical generation and larger proportion is exported, Figure 1 shows Botswana coal exports. Through thermochemical processes such as gasification and pyrolysis, products like char, liquid and gaseous fuels can be produced from coal and biomass and/or animal waste. Char can be used to improve soil quality of Botswana sandy soils as it has been proven to hold moisture and also as a source of energy for cooking.

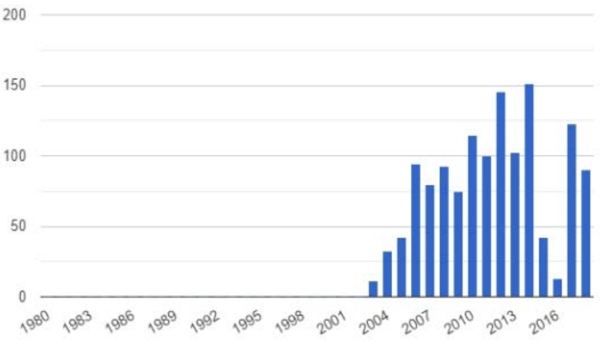

Figure 1: Botswana's Coal Exports

2 METHODOLOGY

2.1 Proximate analysis

Morupule coal from Morupule Mine and cow dung sourced from local farms were air dried for 2 hours before being used in the experiments. All samples were crushed to <7 mm using a ball mill and the proximate analysis of the samples was performed using a TGA (Leco, TGA 701). Morupule coal has a higher moisture content and higher fixed carbon values than cow dung. The carbon content can be further improved by thermochemical means such as pyrolysis, gasification and carbonization to enhance the efficiency and electrical production in the plant. Thermochemical means remove volatiles in coal, this then increases the fixed value percentage.

2.2 Blending ratios

Morupule coal and cow-dung were co-pyrolyzed to produce char. Coal and cow-dung were blended in different ratios as shown in Table 1. This was so as to see the effect of the ratio of char proximate properties.

Table 1: Ratios of coal and cow dung blends

Experiment	Coal (%)	Cow dung (%)
1	0	100
2	50	50
3	60	40
4	70	30
5	80	20
6	90	10
7	100	0

2.3 Fixed bed reactor

Figure.2 shows the fixed bed reactor where the pyrolysis reactions took place. There is a batch reactor where a sample is placed and condensers which condense the oil fraction from the pyrolysis, the non-condensable gases are then sent to the gasometer as indicated in Figure 3. The reactor was set to 500°C. The condensers were also set to different temperatures with the tertiary condenser at 150°C, secondary 75°C and the primary condenser 25°C at room temperature. The sample was placed in the batch reactor where it was heated in the absence of oxygen by using argon and the volatiles were send to the condenser. These volatiles were then condensed in the various condensers while the incondensable gases go to the gasometer. Char remained in the reactor, where it was allowed to cool after the experiment was complete. This char was then collected for analysis.

Figure 2. Fixed bed batch pyrolysis plant

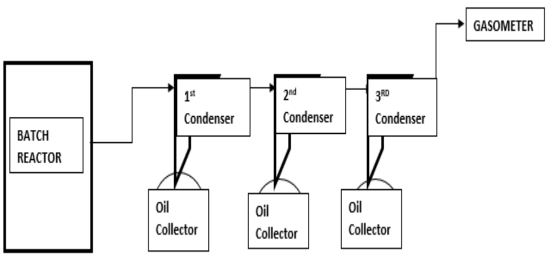

Figure 3. Material flow in the fixed bed batch pyrolysis plant

2.4 Caloric value

This is heat released when a fuel burns in excess oxygen. Caloric values were obtained by using the AC600 calorimeter. Calorific values of the chars after pyrolysis were done so as to compare the caloric values of raw coal and cow-dung.

3 RESULTS AND DISCUSSION

3.1 Proximate Analysis

Table 2 shows the proximate analysis of the feedstocks (coal and cow dung). The ash value of cow-dung is greater than that of coal while the fixed carbon of coal is greater than that of cow-dung which goes hand in hand with a research done by [8]. The chars obtained after pyrolysis experiments were tested for moisture content, ash, volatile matter and fixed carbon and the results are shown in Figure 4. The fixed carbon content increases with increase in coal to biomass ratio. The ash fraction is the highest at 100% biomass in the blend Figure.4, and as the coal ratio increases the ash fraction decreases. This shows that blending coal with biomass has improved the burning of biomass as it has lesser ash.

Table 2: Proximate analysis of raw materials

Name	Moisture	Volatile	Ash	Fixed Carbon
Coal	5.4	25.5	32.8	36.2
Cow dung	3.8	20.6	82.2	3.3

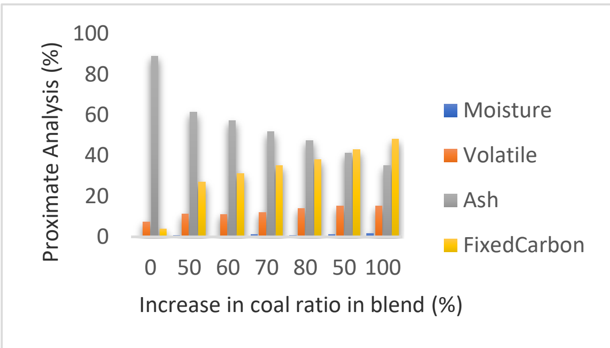

Figure 4:Proximate analysis of chars

3.2 Calorific value of the chars produced

Results for calorific values of raw and chars are shown in Figure 5. Calorific value was the highest when the coal was not blended with cow dung and the lowest when cow-dung was pyrolyzed at 100% Figure 5. The blend with the highest calorific value is when coal is at 90%. Figure 5 also depicts that an increase in coal to biomass ratio is directly proportional to an increase in the calorific value.

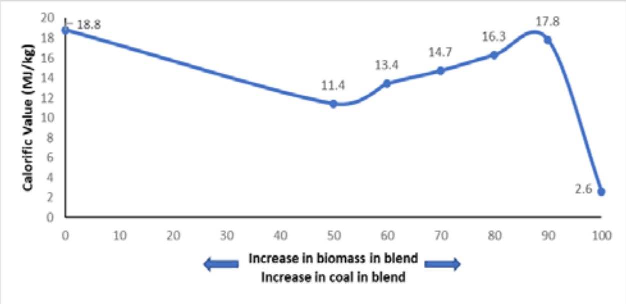

Figure.5:Calorific values of the chars

4 CONCLUSION

This work has shown the possibility of producing char from co-pyrolysis of coal and cow dung. The blending resulted in char with a higher energy content than that from cow dung and its pyrolytic char. This work demonstrated the possibility of addressing both the energy and environmental challenges by utilizing coal and cow dung.

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